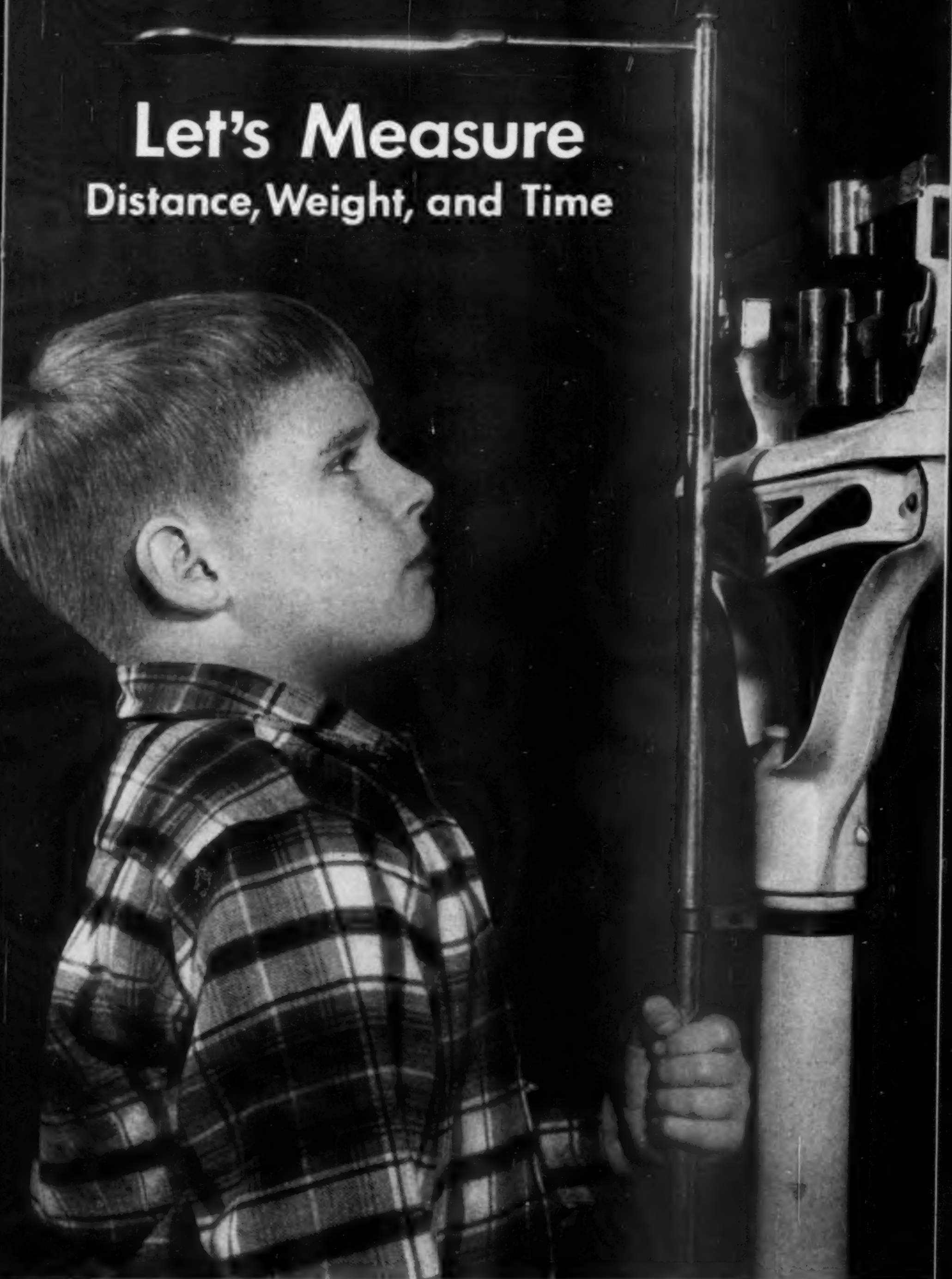
Let's Measure

Distance, Weight, and Time



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LET'S MEASURE

by Verne N. Rockcastle

When you wake up, what do you do before you arrive at school? Perhaps you wash, dress, eat breakfast, and then walk or ride to the school building. Many of the things you do or use between waking and arriving at school are measured in some way.

The clock that wakes you measures time. You wash in water that is heated in a tank with a thermostat to measure and control the temperature. A meter in the basement or outside the house measures the electricity or the gas that the hot-water heater uses. The clothes you wear—your shoes, socks, pants or dress, hat, gloves and coat—all have their standard sizes. The cereal you eat for breakfast comes in a box containing just so many ounces. Your mother may add a certain number of cups of water to the cereal she cooks. On it you may sprinkle a teaspoon of sugar, then pour milk from a quart bottle. Part of your breakfast may be cooked on a stove whose burners have "high," "medium," "low" and "simmer" positions. The morning news can be heard when the radio is tuned to a particular frequency on the dial. When you get ready for school, you may put on a sweater or a jacket, depending upon the outside temperature. The school bus comes by at a certain time. Your bus has its own license plate and bus number to distinguish it from the other buses. It may travel in various directions and at varying speeds before it lets you off at the school building. Or perhaps you ride your bicycle instead of the bus. Is your bicycle a 20-inch, a 24-inch, or a 26-inch one? How many pounds of air do you keep in the tires? How far and in what direction do you ride to school? How long does it take you?

When you think of all the things you do, the machines you use, and the games you play that make use of some kind of measurement, you will be amazed at how important is our ability to measure. Is there any hour during the day that you do not measure in some way: distance, time, temperature, weight, or some other quantity?

to make a list of such expressions and then find out what different persons would estimate their distance to be.

How long? How far apart?

You may be familiar with the names of the common units of distance that are used in our country. They include the mile, the rod, the yard, the foot, and the inch. Do you know how each compares with the others? The table below may help you.

Some other units of distance that may not be so familiar to you as those in the table are used for special purposes. The *chain,* once commonly used by surveyors, equals 66 feet. 80 chains equal 1 mile. If you have travelled on the New York State Thruway, you may have noticed the metal posts along the side of the road, each one with a reflector that helps to mark the side of the road at night. These posts are located a certain number of chains apart, all along the Thruway. Watch for the mile marker on one of the posts. Counting this post as number one, count each post until you come to the next marker. How many posts did you count? Can you tell how many chains apart the posts are? (Remember that there are 80 chains in a mile). How many feet apart are the posts?

The 66-foot chains of the old surveyors had 100 *links.* Today, however, surveyors use steel tapes that are 100 feet or 200 feet long. Their tapes are marked in feet and tenths of feet instead of inches as are most of our rulers. A surveyor who measures the distance 125 feet, 3 inches, would write it as 125.25 feet, since 3 inches is ¼ foot, or .25 feet.

If you were measuring the distance between two points on a slope, how would you do it? Would you measure the distance along the slope, or would you measure the distance horizontally (on the level)? If you were buying a piece of land that sloped, would you want it measured along the slope, or horizon-

UNITS OF DISTANCE

Units	Miles	Rods	Yards	Feet	Inches
1 mile =	1	320	1760	5280	63 360
1 rod =	.003 125	1	5.5	16.5	198
1 yard =	.000 568	.181 818	1	3	36
1 foot =	.000 189	.060 606	.333 333	1	12
1 inch =	.000 016	.005 051	.027 778	.083 333	1

Distance Is 1-D

Are you taller than you are wide, or wider than you are tall? This may seem like a silly question, because the answer is obvious. Now lift your arms out to the side and reach as far as you can. Are you taller than you are wide, or wider than you are tall? How can you tell?

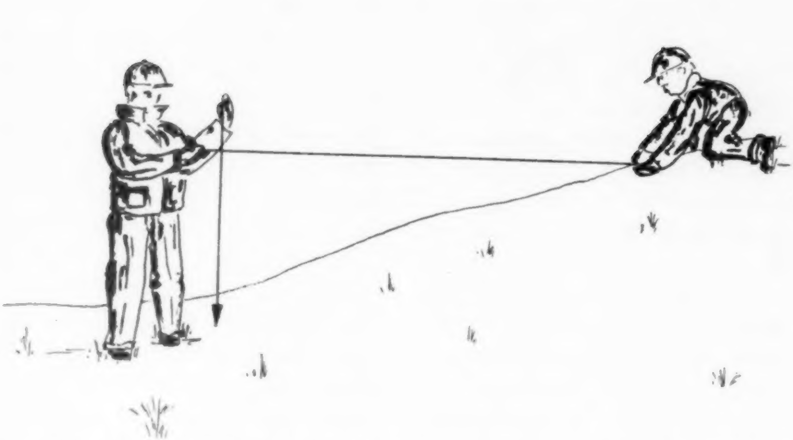
To answer this question you probably stretched your arms out against a wall, had someone mark the points where your fingertips came, and then measured the distance between your fingertips with a ruler. Did you use a foot ruler or a yardstick? Whatever you used, you could have found similar rulers at school or at a friend's home. At least your ruler was marked off in the same units (inches, feet) that any other ruler in common use in our country would be. How these rulers were developed, and what kinds of rulers are used in other countries is interesting to learn. This Leaflet will tell you something about such measuring sticks. An encyclopedia and the books listed at the end of this Leaflet will also help you.

Ancient man probably described with grunts and crude drawings how far it was to the river where there were many fish to catch. Later, in Egyptian times, more accurate measurements of distance were necessary for such things as the building of ships, temples and pyramids, the digging of canals, and the mapping of coastlines. For the construction of their ornate buildings, the Greeks and the Romans depended on still more accurate measurements. More than two centuries B.C. (before Christ), Eratosthenes, a Greek astronomer, even determined the circumference of the earth with an accuracy that is considered remarkable. Through the ages our ability to measure has steadily improved, until today scientists can measure distances smaller than 1/10,000th the thickness of this page!

In spite of the accuracy of many measuring devices, however, you will still hear some persons use expressions such as:

"a stone's throw"
"a block away"
"spittin' distance"
"down the road a piece"

In the Adirondacks I saw a road sign that advertised a bait store "200 fish-lengths" down the road. I wonder just how far that is. You can probably think of other expressions of distance that are commonly used, but which are not at all accurate. You may wish



A plumb-line helps mark the end of a horizontal measurement made on a slope

statute miles. The nautical mile is based on the distance around the earth (the earth's circumference) at the equator. If you divided the equator into 360 equal parts (called degrees), and then divided each of these degrees into 60 smaller parts (called minutes), each of them would be one nautical mile in length. Large ocean liners such as the H.M.S. Queen Mary and the S.S. United States have top speeds of more than 30 nautical miles per hour, or as seamen would describe it, more than 30 *knots* (a *knot* is one nautical mile per hour). Imagine a ship more than a thousand feet long plowing through the water at 35 miles per hour!

How deep?

On shipboard the *fathom* is used as a unit of depth. A fathom equals six feet. Sometimes a weighted line with knots spaced a fathom apart is tossed overboard at intervals to determine the depth of the water. The sailor using the line would note at what knot the water level came and would call out to the helmsman (who steered the boat) how many fathoms deep the water was at that point. If the water were one fathom (6 feet) deep, he would call out, "Mark one!" If the water were three fathoms (how many feet?) deep, he would call out, "Mark three!" If it were two fathoms deep (safe for most riverboats) he would

tally? Why? How would you like it to be measured if you were selling the land?

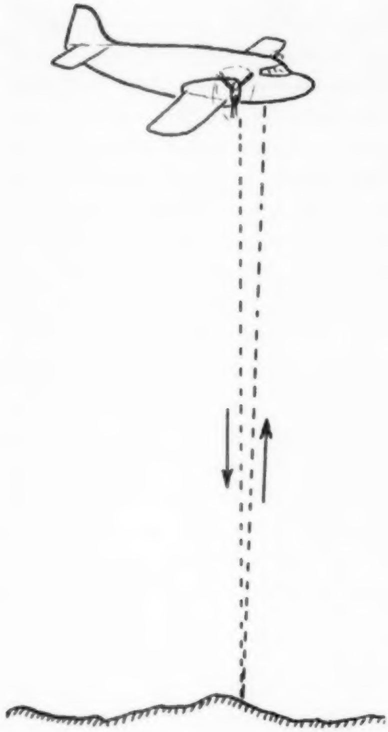
In order to make land measurements mean the same thing to all persons, land measurements are made horizontally. The diagram on page 7 shows how horizontal distance is measured on a slope. The tape is held level. The distance is measured from the higher point to a *plumb line* (a string with a weight) that is held directly over the lower point. Measuring up or down hill is like measuring in steps. The base of each step is where the plumb line touches the ground. Watch a surveyor measure a slope. Can you see how he uses a plumb line to help find the correct horizontal distance?

Distances on highways and waterways are usually measured in miles, but the length of a mile over land may differ from the length of a mile over water. On land the *statute mile* (5,280 feet) is used. This is the mile that is registered on an automobile odometer (o-dah'meter). (A *speedometer* shows how fast you are going, but the distance you have travelled is registered on an *odometer.*) Perhaps you have an odometer on your bicycle and can find out how many miles it is to your school, to the store, to church, or to the playground.

A car's odometer shows how many miles it has travelled. A road map shows how many miles a car must travel to go from one town to another. Look at a road map of your state. Can you find your home town? Look for another city or town that is near your home. Can you tell from the map how far it is to that city or town? Next to the lines that represent roads, most road maps show the distance between major cities and towns. In addition, there is a *scale of miles* somewhere on the map. This shows how distances on the map compare to real distances. Can you find the scale of miles on your road map?

On some maps one inch represents one mile; on some one inch represents 10 miles; and on others one inch may represent 100 or more miles. Sometimes the scale is given as 1:62,500. This means that one inch on the map represents a distance of 62,500 inches or about one mile. What is the scale on your road map? What is the scale on a topographic map of your area? How many maps with different scales can you find?

At sea the *nautical mile* is commonly used to measure distance. It is longer than the statute mile. One nautical mile equals 6087.27 feet, or 1.1516



No guessing here, either!

tim′eter) that works like an aneroid barometer. As the plane flies higher, the air pressure decreases and the altimeter needle moves across a dial that is marked off in thousands of feet above sea level instead of inches of mercury as most barometers are. Pilots who use a pressure altimeter must constantly re-set the instrument for the pressure changes that occur from day to day and from place to place, even at the same altitude. A pilot flying from a high pressure area toward a low pressure area might be losing altitude, even though he flew so as to keep his altimeter reading constant. This could be dangerous in mountainous country.

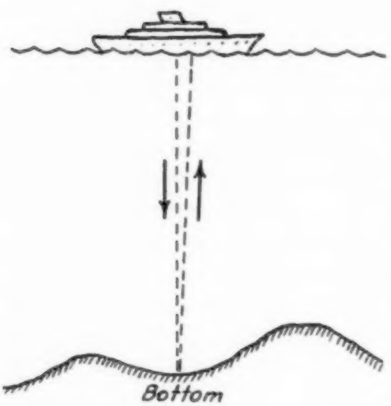
Pressure altimeters do not indicate actual altitudes above land, but only the approximate altitude above sea level. A pilot using a pressure altimeter must know the height of the land below him in order to know how far above the ground he is. The *radio altimeter* was developed to give the pilot his exact altitude above the ground. It sends out a radio signal from the plane to the ground. The radio signal is reflected from the ground back to the plane. The time interval

This pressure altimeter indicates 1700 feet above sea level—not above the ground

call out "Mark twain!" Samuel Clemens, the famous author of *Huckleberry Finn* and *Tom Sawyer,* got his pen name from this expression of water depth, since it was a safe depth for most of the riverboats on which he travelled. Some boats still use this method of sounding.

The depth of the sea was once determined by lowering a weighted line to the bottom, then measuring the line. Modern ships make use of an "aquatic echo," a sound that originates at the ship, bounces off the ocean floor, and is received back at the ship. The time interval between sending and receiving the signal is an indication of the ocean's depth at that point.

No guessing here!



How high?

Vertical measurements on the earth are necessary to find the heights of mountains, clouds, airplanes, missiles and artificial satellites. You may already know that the earth is about 8,000 miles in diameter. Do you know how the height of the tallest mountain compares with this? The top of Mt. Everest is 29,028 feet above sea level. This is about five and one-half miles high. The deepest part of the ocean, in the Marianas Trench near Guam, is 35,640 feet or about seven miles below sea level. As you can see, the highest and the lowest points are only small unevennesses on the earth's surface. They represent less roughness than can be found on the skin of an orange. The tallest building (the Empire State Building in New York City) is only 1,250 feet tall. This would be little more than a dust speck on our orange!

Airplanes normally fly at altitudes below 20,000 feet (above sea level), although jets can fly as high as 40,000 feet and rockets can fly much higher. (Powerful rocket engines have already pushed objects right outside the earth's magnetic field!) The altitudes of aircraft are determined in either of two ways. One makes use of a *pressure altimeter* (al-

between sending and receiving the signal indicates the plane's true altitude above the ground.

Miles and meters

Distances in our country are measured in the English (United States) system, using miles, chains, rods, yards, feet and inches. In many other countries, however, a different system is used. It is the *metric* system, based on the *meter* as a unit of length. A meter is longer than our yard (39.37 inches as compared to 36 inches). The meter, like the nautical mile, is based on the distance around the earth at the equator. The standard meter is 1/10,000,000th of a quadrant. A quadrant is one-fourth the distance around the earth. So a meter is 1/40,000-000th the distance around the earth at the equator.

A thousand meters equals a *kilometer* (kil'o-meter). In many European and Asiatic countries this measure is used to describe land distance just as we use the mile. A kilometer is shorter than our statute mile, however. One kilometer equals 0.621 miles; one mile equals 1.609 kilometers. The speedometers of French, German and Italian cars show speeds in kilometers per hour, and their odometers show the kilometers travelled.

A hundredth part of a meter is called a *centimeter*. It is used in the metric-system countries just as we use the inch. A thousandth part of the meter is called a *millimeter*. It is nearly 1/25th of an inch. As we go from the mile to smaller and smaller units in the United States system, we use the numbers 5280, 16.5, 3, 12, 1/8 and so on. We do not divide each unit into the same number of parts to make the next smaller unit. In the metric system, however, each unit is divided into ten parts to make the next smaller unit:

1 kilometer	=	10 hectometers
1 hectometer	=	10 decameters
1 decameter	=	10 meters
1 meter	=	10 decimeters
1 decimeter	=	10 centimeters
1 centimeter	=	10 millimeters

The millimeter, centimeter, meter and kilometer are most commonly used in everyday measurement.

Measuring small distances

For most measurements in the metric system the millimeter, or a fraction of a millimeter, is a sufficiently small unit of distance or length. Modern science demands much smaller units of measurement, however. The thickness of films, the size of bacteria and viruses, the crystalline structure of metals, and the grinding of lenses and mirrors all

require precision measurements for which the millimeter is far too large a unit. Instead, the *micron,* which is one millionth of a meter, or one thousandth of a millimeter, is used. For measurements of cells and other tiny things even the micron is too large a unit, so the *millimicron* is used. A millimicron is 1/1,-000,000th of a millimeter, a measure so small that 70,000 millimicrons laid end to end would just equal the thickness of this page! Sometimes even the millimicron (often abbreviated μ is not small enough to use as a convenient unit of length. Light waves, for example, are so small that a special unit, *Angstrom unit,* is used to describe them. This tiny unit, named after a Swedish physicist, Anders Angstrom, is only 1/10th as long as a millimicron. This page is more than a half-million Angstrom units thick!

Recently a new unit of length has been used to describe the nuclei of atoms. It is called the *fermi,* after the famous atomic physicist, Enrico Fermi. A fermi is so small that 70,000,000,000 of them would equal the thickness of this page! It is difficult to imagine a unit so small. The following table may help you to see the relation of the smaller units of the metric system to each other:

1 centimeter	= 10 millimeters
1 millimeter	= 1000 microns
1 micron	= 1000 millimicrons
1 millimicron	= 10 Angstrom units (abbreviated Å)
1 Angstrom unit	= 100,000 fermis

Can you find a millimeter on your ruler or on a meter stick? Can you imagine this tiny distance divided into fermis—1,000,-000,000,000 of them?

Measuring large distances

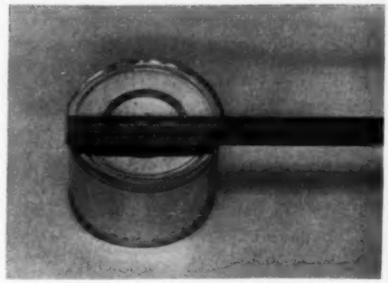
As some scientists work with smaller and smaller distances, others work with larger and larger ones. A mile may seem a long distance to you, particularly if you have to run or walk a mile. It is not very far, however, if you compare it with some dimensions in the sky. The distance around the earth at the equator is about 25,000 miles. The moon, our nearest natural neighbor, is nearly ten times that far away, or about 240,000 miles. The sun is nearly 400 times 240,000 miles away, or about 93,000,000 miles. (The distance from the earth to the sun is known as one *astronomical unit.*) Pluto, the most distant planet, is about 4,000,-000,000 miles away from us. How many astronomical units is that? The nearest star beyond our sun is about 23,000,000,000,000 miles away, and many stars are more than a million times as far away as that! Just as a fermi

seems incredibly small, such astronomical distances seem large beyond our wildest imagination.

The mile and the kilometer are such tiny fractions of the distances between stars that astronomers have adopted a more convenient unit of length for celestial measurement—the *light year.* Light travels through space at the fantastic speed of 186,000 miles each second. This is a little more than seven times around the earth in one second. In one year light would travel 60 (seconds in a minute) × 60 (minutes in an hour) × 24 (hours in a day) × 365 (days in a year) × 186,000 miles. That means that in a year's time (31,536,000 seconds) light would travel 5,865,696,000,000 miles! That is the length of a light year. Our nearest star is about four light years away. Isn't it much easier to express its distance in light years than in miles?

To give you some idea of how long a light year is, imagine that each page of this Leaflet is one mile thick. The Leaflet would then be 16 miles thick. A one-inch pile of Leaflets would represent 368 miles. To represent a light year these Leaflets would have to be stacked in a pile more than 250,000 miles high, or would reach beyond our moon.

How many borders (perimeters) can you find in this classroom?



The diameter of this can is 5 inches. Can you find its circumference?

From millimicrons to light years, measurements must be made with precision if scientists are to use these measurements to design better instruments and machines, and to learn more about our universe. In order to make sure that the scale one scientist uses is exactly the same as that which another scientist uses, the United States Bureau of Standards in Washington, D. C. was organized. Here, the standard meter and other standard units of measurements, made of platinum-iridium, are kept in sealed containers. In Paris, London, Moscow, and a few other capital cities of the world are kept similar standards of measurement, all made as nearly identical as possible. You may wish to read about the Bureau of Standards and the work it does. It plays an important role in the scientific achievement of our country.

Borders

Distance is not always measured in a single straight line. Sometimes it is important to know the distance *around* an object, called its *perimeter* (per-im′e-ter). The baseboards and moldings around a room represent its perimeter. A carpenter must know the perimeter of a room in order to purchase enough molding to go around it. The perimeter of a playground indicates how much fence is needed to enclose it. The perimeters of some driveways are brick or concrete curbs. The perimeter of a kitchen counter may be a metal strip. How many things in your home or school represent borders or perimeters?

The perimeter of a rectangle is easy to find. Just add two lengths and two widths. This equals the distance around the rectangle. You can even write this rule as follows:

$$P = 2L + 2W$$

This means that the perimeter equals twice the length plus twice the width. What is the perimeter of this page? of your desk top? It might be fun for each member of your class to estimate the perimeter of the classroom, then measure it to see who comes nearest the correct answer. Can you estimate the

perimeter of your school playground? How can you find out the correct distance?

The perimeter of round objects is called the *circumference* (sir-cum'fer-ence). Suppose you wished to find the circumference of something like a #10 can or a round-topped oatmeal box. There are three ways you could do it. First, lay the can on the floor so it will roll. Where the rim of the can touches the floor, make a mark on both the floor and the can. Roll the can one turn and watch where the mark on its rim touches the floor again. Use a ruler to measure from this point to the first mark on the floor. What is the circumference of the can?

Next, put a string around the can and mark it so that you can remove the string and lay it on a ruler or yardstick. How does this measurement of the circumference compare with what you found by rolling the can?

Now use a ruler to measure the *diameter* (di-am'e-ter means distance across a circle) of the can as shown on page 13. (Make sure the can is not dented or misshapen.) What is the diameter of your can? Now multiply this by the number *3.1416*. How does this result compare with the other two measurements of the can's circumference? Are you surprised that you found the circumference without actually measuring it? Try doing this with a ruler marked in centimeters. Do you find it any easier than working with inches? In what way?

The number 3.1416 is called *pi* (pronounced pie), and is written π. The Greeks, centuries before Christ, knew how much π was. I wonder who discovered it and how. Pages 19 and 21 tell you about some other uses of π.

On page 13 you learned a formula (a rule written with numbers and letters instead of words) for finding the perimeter of a rectangle. Now that you know how to find the circumference of a circle, you can write the following formula:

$$C = \pi d$$

This means that the circumference equals $\pi \times$ diameter. What is the circumference of a circle whose diameter is 1"? 2"? 4"? What happens to the circumference each time you double the diameter? Each time you double the radius? (Remember that the radius is one-half the diameter.)

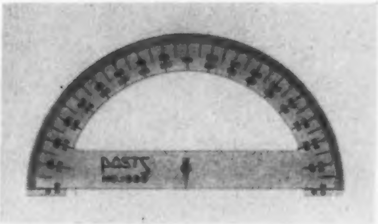
Angles

Just as a foot or a meter can be divided into smaller units, so can a circle. Any complete circle can be divided into 360 equal parts

called degrees (written °). A half-circle divided into 180 degrees (half of 360) is shown at the right. Half of this half-circle marks a right angle or 90°. A corner of this Leaflet page is a right angle, or an angle of 90°. How many other right angles can you find about you? You do not have to look hard to find them do you?

If your school roof slopes, can you estimate how many degrees there are in the angle between a horizontal (level) line and the roof? What is the slope of your roof at home? What is the slope of the steepest hill you slide down in winter? Many persons think the hills they walk or ride on are as steep as 45° (half a right angle), but hills are rarely that steep. Slopes or grades on most highways do not exceed 10°; few railroads exceed 4°; the New York State Thruway's steepest grade is only about 6°.

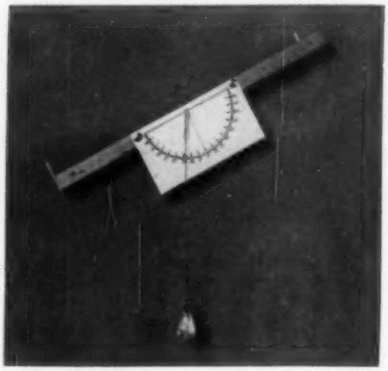
In one hour the minute hand on your school clock moves through a complete circle of 360°. If there are 60 minute marks on the clock face, how many degrees does each minute represent? How many degrees are there between the numbers "2" and "4" on the clock? between 12 and 3? While the minute hand moves 360°, how many degrees does the hour hand move?



Angles on a protractor are measured from the pointer on the straight edge

You can measure angles by comparing them with the half-circle shown above. Such a half-circle, marked in degrees, is often made of plastic or metal and is called a *protractor* (pro-trac′tor). Most stores that carry school supplies sell protractors for a few cents. A protractor will help you find out how many degrees there are in all sorts of angles. It will also help you find distances that are inconvenient to measure.

Suppose you wished to find the height of your school flagpole. Of course you could shinny up the pole with a tape in one hand, but you can also find its height without leaving the ground. To do it, you will need to make a height-finder like the one shown on page 16. You need a stick with some sort of sighting device on it, a weighted string, and a protractor. You can make one by tracing the one shown above. The height-finder in the picture has a peep-hole at one end and a nail that projects



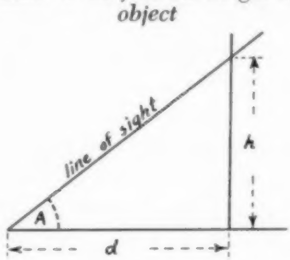
The plumb-line of this height finder shows that the line-of-sight is inclined 27°. What would it read if the stick were level?

upward from the other end the same height as the peep-hole. Tack the protractor to the side of the stick as shown. Drive a small nail into the stick at the center of the protractor's straight edge to support the weighted string (plumb-line). You are now ready to find the height of the school's flagpole.

Stand exactly 40 feet from the base of the flagpole. Sight through your height-finder at the tip of the flagpole. Have someone read the angle of your height-finder as indicated by the plumb-line. How many degrees are there between a horizontal (level) line and your line-of-sight? (If you use a commercial protractor, you will need to count the number of degrees between the "90" mark and the plumb-line.)

Now you can draw *to scale* on a piece of paper what you have observed with your height-finder. Using a scale of 1" represents 10 feet, draw a horizontal line to represent your distance from the flagpole. How long will the line be? At one end of this line draw a long vertical line to represent the *position* of the flagpole. At the other end of the horizontal line, make an angle equal to the angle that you found when sighting on the flagpole tip. Extend this angle until the line crosses the one that represents the flagpole's position. Measure the length of the line that represents the flagpole. Using the same scale of 1" to 10 feet, what distance does this line represent? This is how high the top of the flagpole is *above your eye-level.* Now add the distance from your eye to the ground and you will

Copy the angle of the height-finder at "A". Draw to scale the distance from the observer to the object ("d"). Measure "h" to find the height of the object



have the height of the flagpole. Easy? Yes! Fun? Sure!

Try your height-finder on the school chimney, and on some nearby trees. Sight at different distances from their bases, and try different scales of distance in your drawings. Your teacher may show you a similar method for finding horizontal distances.

Area Is 2-D

Up to now you have read about measurements of only one dimension. That dimension may have been one of distance between two objects, or length, or width, or thickness. To determine *area*, two dimensions must be multiplied. The area of this page, for example, may be found by measuring both its length and its width, then multiplying the two numbers together. When you measured distance (1-D), you used such units as feet, inches, centimeters, and millimeters. Area, because it is measured in two directions (length and width), is described in such units as *square feet*, and *square* centimeters. "Feet" describes distance; "square feet" describes area.

What are the dimensions of this page? Can you find its area? Measure a rectangular desk top as accurately as you can. Multiply the length by the width to find its area. Now ask several other persons to measure the same desk top and find its area. Compare their measurements with yours. Compare their areas with yours. Which differs more from what you found: their dimensions or their areas? Can you find out why this is true? Remember that when several persons measure any distance their measurements usually differ a little. This small variation becomes much larger when it is multiplied by another number. What would happen if you multiplied by still a third number?

The height-finder is being used to find the height of a school flagpole

Area of a parallelogram (A=bh)

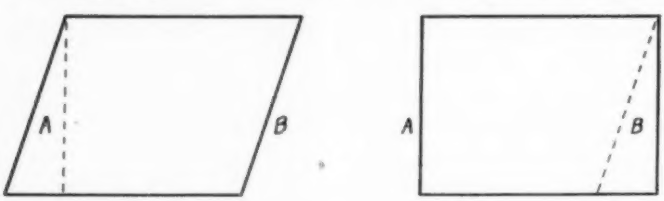
The area of a rectangle is easy to find. You can just as easily find the area of other regular figures. Suppose you wished to find the area of a parallelogram such as that shown on this page. Can you see that the area of the parallelogram is the same as that of the rectangle beside it? To find the area of any parallelogram, multiply the length of its base by its height. Do not measure the height along the slope, but at right angles to the base.

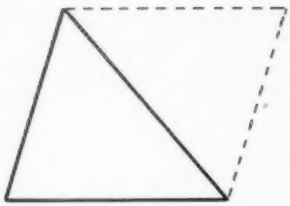
Remove both ends from a cardboard box. Press the box sideways so that its open ends are no longer rectangular. Measure the base and the height of the parallelogram you now have. What is its area? Press the box a little farther "out of shape." What is its area now? Does the base of the parallelogram change in length as you change its shape? Does its height change? When would the area become zero? When is the area greatest?

Area of a triangle (A=1/2 bh)

The area of a triangle can be found by multiplying its height by *half* its base. (Is this the same as multiplying its base by half its height?) In the triangle pictured on page 19, imagine a parallelogram made by drawing lines from two points of the triangle as shown. You have learned that the area of the parallelogram equals the base multiplied by the height. Can you see that the triangle is just *half* the parallelogram? Perhaps you will want to find the area of such polygons (many-sided figures) as those shown on page 19. If you draw lines from the center of a regular polygon to its points, you can divide it into triangles, the areas of which you now know how to

The parallelogram (a 4-sided figure whose opposite sides are parallel) becomes a rectangle if piece "A" is moved to "B". The areas are the same





The area of the triangle is one-half that of the parallelogram ($\frac{1}{2}$ bh)

find. As shown below, you can also divide irregular polygons into triangles.

Area of a circle ($A = \pi r^2$)

To find the area of a circle, first find its radius. (The radius is one-half the diameter.) Multiply this number by itself (this is called *squaring* the number), then multiply the product by π (3.1416). Remember to write the area in *square* units.

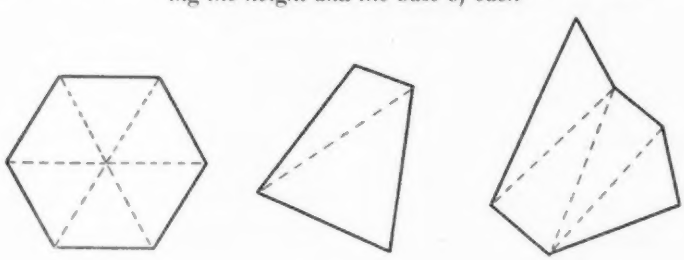
One circle at the top of page 20 has a radius of 1″ (one inch). Can you find its area? What would be the area of a circle whose radius is 2″? 4″? What happens to the area of a circle each time you double the radius? What happens if you decrease the radius one-half?

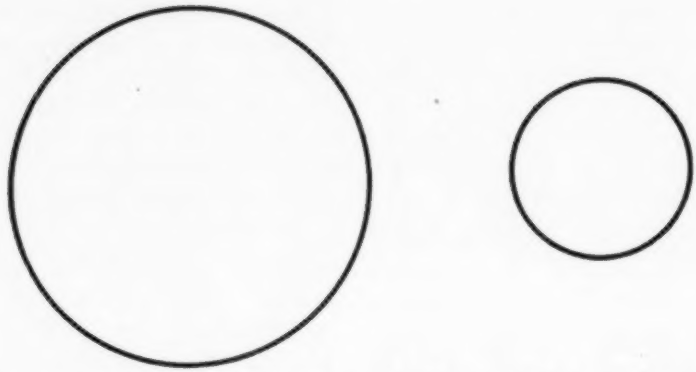
Land area is usually expressed in acres or *square* miles. An acre contains 43,560 square feet. An acre may have many dimensions, so long as the area equals 43,560 square feet:

1 acre = approximately	208 feet	x	208 feet
	100 feet	x	435 feet
	50 feet	x	870 feet
	25 feet	x	1740 feet
	10 feet	x	4356 feet

Apple trees are often planted about 40 feet apart. This spacing permits 25 apple trees to the acre. Christmas trees that are spaced 6 feet apart can be planted 1000 to the acre. An acre of corn might be expected to produce 80 bushels. An acre of potatoes might be expected to

Polygons are just combinations of triangles whose areas you can find by measuring the height and the base of each





The larger circle has twice the diameter of the smaller, but four times the area!

produce 300 bushels. Try estimating the size of fields near your home, then check with the owner to see how close your estimate is to the correct size. How does your yard compare to an acre?

You know that square inches, square feet, square centimeters and square meters are units of area. Any unit of distance up to a mile can be used as a unit of area by adding the word "square" to it. Remember, however, that a "square foot" and "foot square" mean two different things. A square foot may be 1/2 foot by 2 feet; a foot square must be 1 foot on each side. Be sure you use the correct expression. The following table may help you understand the relation between various units of area.

1 square mile	=	640 acres
1 acre	=	43,560 square feet
1 square yard	=	9 square feet
1 square foot	=	144 square inches
1 square meter	=	10,000 square centimeters
1 square centimeter	=	100 square millimeters

Volume Is 3-D

Volume of a box (**V=lwh**)

You have learned how to find area by multiplying together two dimensions. You can find *volume* by multiplying area by a third dimension, height. Area is expressed in such units as square feet and square centimeters. Volume is expressed in such units as *cubic* feet and *cubic* centimeters. For example, suppose a cigar box were 9″ long, 6″

wide, and 2″ deep. The area of its top would be 9″ × 6″ or 54 square inches. Its volume would be 9″ × 6″ × 2″ or 108 *cubic inches.*

Can you find the volume of a shoe box that is 12″ long, 5″ wide, and 3″ deep? Is the volume of this box greater or less than one that is 10″ long, 10″ wide, and 2″ deep? How does it compare with the volume of three cigar boxes?

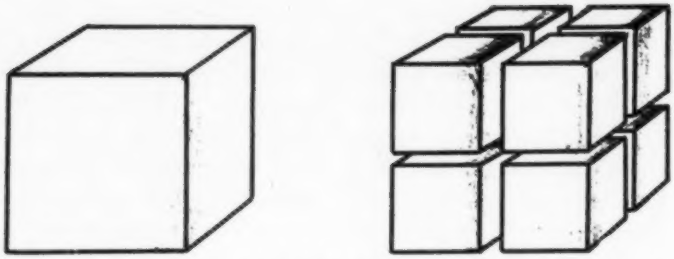
Volume of a cylinder ($V = \pi r^2 h$)

Finding the volume of a rectangular box such as a cigar box was easy. The same procedure applies to cylindrical boxes. Measure the top of a round-topped oatmeal box and find its area. (Look back to page 19 if you do not remember how.) When you have found the area of the top, how do you find the volume? Multiply the area of the top by the height of the box, of course! Can you see that this is the same way you found the volume of the cigar box, except that the oatmeal box has a base of different shape? How many cubic inches are there in an oatmeal box? If your mother starts with a full oatmeal box and uses two cubic inches of oatmeal every morning, how long will the box of oatmeal last?

Many things that you buy at the store, and many things that are used in industry are manufactured or sold by volume. For example, milk is sold by the quart or pint, as are ice cream, most beverages, oysters, mayonnaise, motor oil and paints. Gas for your auto is purchased by the *gallon,* as are cider, fuel oil, maple syrup and vinegar. Gas for heating and cooking and the water from public water systems are purchased by the cubic foot. A cubic foot equals about 8 gallons. Can you read your water meter (if you have one), then read it again a week later and find out how many cubic feet, and how many gallons, of water you used in your home in a week's time?

Sand, gravel, topsoil, and ready-mixed concrete are usually purchased by the *"yard,"* meaning a cubic yard. A yard of concrete weighs more than 2 tons. The large ready-mix trucks can carry as much as 6 yards of concrete, or 12 tons, in addition to the weight of the truck. Is it any wonder that occasionally a truck backing up to a newly-laid house foundation pushes in the wall because of the tremendous weight on the soil around it?

You may wish to find the volume of such things as your classroom, a swimming pool, or your home freezer. As you practice



When a 1-inch cube is divided into half-inch cubes, the surface area is doubled although the volume remains the same

finding volumes (and areas) you will soon become skillful at estimating the correct answers before you even begin the arithmetic.

Surface vs. volume

There is an interesting relation between the volume of an object and its surface area. Imagine a cube that is 1 inch on each side. Its volume is 1 cubic inch. It has 6 sides, each with 1 square inch of area, or a total of 6 square inches. The diagram above shows what the cube would look like.

Now suppose you cut the cube into smaller cubes, each of which is only ½ inch long on a side as shown. How many cubes would you get from the large one? The volume of each small cube would be only ⅛ cubic inch. Can you see why? Each side of a small cube would have only ¼ square inch of area. All 6 sides of one of the small cubes would total 6 × ¼ (1½) square inches. The 8 small cubes together would have a total area of 8 × 1½, or 12, square inches. Do you see that by cutting the large cube into cubes only half as long, the total surface is increased from 6 square inches to 12 square inches? Can you guess what would happen if the ½-inch cubes were again cut into smaller ones ¼ inch long? Suppose these were again cut into smaller and smaller ones. Their total surface would increase tremendously, even though the total volume remained unchanged. Does this help to explain why powdered sugar, which has much more surface area than a sugar cube, dissolves faster than a sugar cube? Can you see now why a crushed ice cube cools a glass of water faster than does an unbroken ice cube? There really is no more

ice, but there is much more exposed surface. Think about and look for other examples of the use of small particles with relatively more surface than large particles.

Irregular volumes

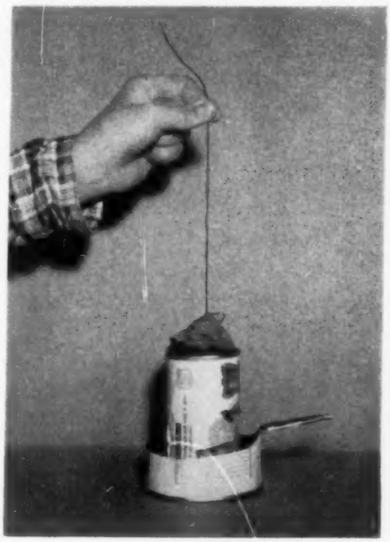
The volume of irregularly shaped objects can often be measured easily by finding out how much space they occupy *under water*. Suppose you wished to find the volume of a stone that is irregular in shape. To do so, fill a container with water to the brim, tie a string on the stone, and slowly lower the stone into the water. Catch the water that runs over. Measure this overflow in a graduated cylinder or a measuring cup and you will have the volume of the stone (and string). Try this with several irregularly-shaped objects, but do not use objects that will dissolve or be spoiled by the water.

If you do not have a graduated cylinder or a measuring cup, you can use a balance to weigh the overflow water. As you will learn on page 25, water weighs 1 gram per cubic centimeter. If the overflow water weighs 10 grams, then the volume of the object is 10 cubic centimeters. If the overflow water weighs 16.3 grams, then the object has a volume of 16.3 cubic centimeters. How easy it is to find volumes by this method! Remember, however, that one number cannot be used for both weight and volume of water except when you use the metric system.

You have learned to find the volume of an irregular object that is heavier than water. Now here's a puzzle: how can you find the volume of an object that does not sink—a cork, for example?

Just as there are many different units of distance and area, there are many units of volume.

As the rock is lowered into a full can of water, it forces out its own volume of water



UNITS OF VOLUME

Units		Cubic inches	Cubic feet	Cubic yards
1 cubic inch	=	1	0.000 578 704	0.000 021 433
1 cubic foot	=	1728	1	0.037 037 0
1 cubic yard	=	46 656	27	1
1 cubic centi.	=	0.061 023 38	0.000 035 314	0.000 001 308
1 cubic deci.	=	61.023 38	0.035 314 45	0.001 307 943
1 cubic meter	=	61 023.38	35.314 45	1.307 942 8

Units		Cubic centimeters	Cubic decimeters	Cubic meters
1 cubic inch	=	16.387 162	0.016 387	0.000 016 387
1 cubic foot	=	28 317.016	28.317 016	0.028 317 016
1 cubic yard	=	764 559.4	764.559 4	0.764 559 4
1 cubic centi.	=	1	0.001	0.000 001
1 cubic deci.	=	1 000	1	0.001
1 cubic meter	=	1 000 000	1 000	1

This list of volumes and their equivalents will help you see how each compares with the others

Weight

You know that groceries such as butter, meat and many vegetables are sold by weight. Many things besides groceries are also sold by weight. Coal is usually sold by the *ton*. Perfume, on the other hand, is sold by the *ounce* or *dram*, tiny measures of weight when compared to tons. Chemicals, fertilizer, cement, nails, rope, seed, auto licenses, and even mailing costs are based on weight. Can you think of other things whose cost depends upon weight?

When you measure weight, you really measure how great the pull of the earth is on the object you are weighing. This pull, called *gravity*, depends upon several things such as the kind and amount of material in the object, and how far it is from the center of the earth. You know that iron weighs more than wood. Perhaps you also know that an object several hundred miles from the earth's surface (such as an artificial satellite) weighs less than it does at the earth's surface. As you read more about science you may learn that the weight of an object depends upon even its motion.

Comparing weights

Some materials are very heavy, even in small bits. Lead, mercury, and uranium are some of these. Large quantities of some

other materials are extremely light in weight. Hydrogen gas, for example, is lighter than anything else we know of. A balloon filled with hydrogen will lift more than a similar balloon filled with any other material. Feathers and cork seem very light because equal quantities of many more familiar things such as iron, wood and water are much heavier. In order to compare the "heaviness" of different materials, we must compare equal volumes of the materials. It wouldn't be fair, for example, to weigh a cubic yard of cork, then weigh a cubic inch of iron, and conclude that cork is heavier than iron. Either a cubic foot or a cubic centimeter is usually used as the standard volume for weight comparison. The following table gives the weight of a cubic centimeter and a cubic foot of a few materials:

Material	grams/cc.	lbs./cubic foot
aluminum	2.7	169
cork	0.25	16
glass	2.6	160
iron	7.8	486
limestone	2.7	170
water	1.000	62.5
wood	0.32-0.97	20-60

Scientists use the number that expresses the *weight per cubic centimeter* to compare the "heaviness" of many materials with that of water. You can see from the table that water weighs 1.00 gram per cubic centimeter. Iron weighs 7.8 grams per cubic centimeter so it is 7.8 times as heavy as water. How heavy is glass compared with water? cork? limestone? Materials that sink in water have specific gravities that are greater than 1.00. Materials that float ordinarily have specific gravities that are less than 1.00. Kerosene has a specific gravity of 0.82. Will it sink or float when it is put into water?

Units of weight

Two systems of weight measurement are in common use today. In our country we use the English (United States) system of ounces, pounds, and tons. For weighing precious metals, gems, and drugs, the *troy* scale (1 pound = 12 ounces) is used. For weighing everything else, the *avoirdupois* scale (1 pound=16 ounces) is used. In all measurements in the English system this Leaflet uses avoirdupois weights.

In some European countries the metric system is used. Grams, kilograms and metric tons are their commonly used units. A boy who weighs 80 pounds would be described by the French as weighing 35 "kilos," meaning 35 kilograms. A kilogram equals 2.2 pounds.

UNITS OF WEIGHT

Units	Grains	Grams	Drams	Ounces	Pounds	Kilograms
1 grain	1	.065	.037	.002	.000 143	.000 065
1 gram	15.43	1	.564	.035	.002 205	.001 000
1 dram	27.34	1.772	1	.062 5	.003 906	.001 772
1 ounce	437.5	28.35	16	1	.062 5	.028 349
1 pound	7 000	453.6	256	16	1	.453 6
1 kilogram	15 432	1 000	564.38	35.27	2.2	1

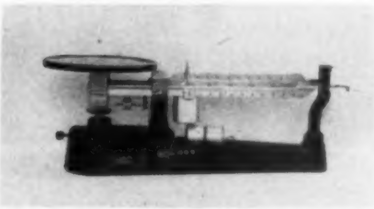
This list of weights and their equivalents will help you see how the various English and metric units of weight compare

Net weight

A grocery store is a good place to learn some simple facts about weight. The next time you go shopping, look at the labels on some of the cans and packages. Can you find the *net* weight printed on the labels? Net weight means the weight of the material *inside* the container. It does not include the weight of the container. Compare the net weights of several cans of olives. Compare tall cans with short cans, slender with stout. How does the net weight of a tall, slender can of olives compare with that of a short, wide can? Do you find other canned foods that show similar differences in net weight in cans of different shape?

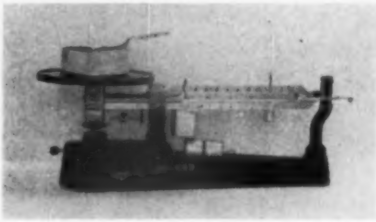
Cereal, candy, toothpaste and other easily-crushed items are often packaged in crush-resistant containers. The containers make it appear as if they contain more material than you really find. Do not be misled by the size or shape of the container. Remember that the net weight is a true measure of what it contains.

This beam balance reads "zero". The three scales of the beam show grams, hundreds of grams, and tens of grams



Balances and scales

There are two instruments you can use to determine weight. One is a *beam balance* such as is used in most grocery stores, doctors' offices, and laboratories. A beam balance has an arm or beam that pivots freely at one point. The object to be weighed is placed at one end, and the beam is balanced (leveled) by adding known weights to the other end. On the beam balance



The pan and the water displaced by the rock on page 23 weigh 85 grams. The pan alone weighs 51 grams. What is the volume of the water? of the rock?

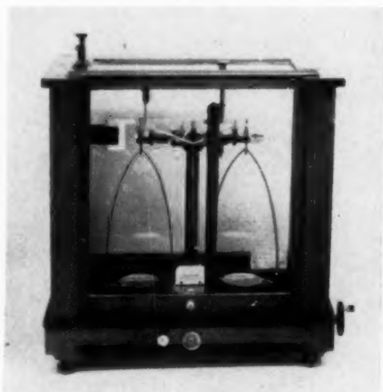
shown (bottom, right) the pivot is midway between the two pans (like a seesaw). When the arm of the balance is level as indicated by the pointer, the sum of the known weights on the right pan equals the weight of the unknown object on the left pan.

The other balances shown here have a beam whose pivot is near the left-hand side. A sliding indicator is moved to the right along the beam until it balances the object being weighed. If there is a balance similar to that shown on the cover, at school, stand on it and weigh yourself. Can you find the place where the indicator just balances your weight? What happens if you move the indicator farther to the right? to the left? If a heavier person gets on the "scales" (balance), what must he do to the indicator?

Store balances often have a rotating cylinder instead of a sliding indicator. Prices are marked on the cylinder so that the grocer doesn't have to multiply the unit price by the weight. He can read the total price directly. The next time you buy something that is weighed, ask the grocer if you can look at the drum that he reads when he weighs your purchase. Can you see the column of weights? Can you find the price of the item you are buying?

Commercial balances are required by law to be checked from time to time by someone from the Bureau of Weights and Measures. When the balances are checked for accuracy, a special stamp is fastened to each balance after it has been approved. Can you find one on the balance at the grocery store?

This analytical balance is so sensitive that it is operated in a glass case so air currents won't affect the measurement



A less accurate, but commonly used, weighing device uses a spring instead of a pivoted beam. It is called a "spring balance," although it is not a true balance. On the simplest ones a pan is suspended by a coiled spring. When a weight is placed in the pan, the spring stretches. The amount of stretch is an indication of the weight. Have you any spring balances at school?

Coiled springs may also be compressed as weight is added. Bathroom scales and kitchen scales often use such a spring. The more weight that is applied to this spring, the more the spring is compressed. In time the elasticity of the spring may change, however, so that spring balances are not as accurate as beam balances. Some store balances even have on them the following words: "Honest weight —no springs." Can you find these words on any store balance in your neighborhood?

Balances may be large enough to weigh heavy trucks loaded with coal or scrap iron. As you ride along the highway, look for a truck weighing station. Here heavy trucks are weighed to see whether they comply with the legal load limits. The capacity of New York State-licensed trucks is indicated on the side of the trucks, along with the letters "NYUW," "NYML" and "NYMGW". Can you find out what these letters mean?

Truck balances are large, but others, called analytical balances, are used for weighing tiny amounts of things like chemicals and tissues. Some are so sensitive that they can weigh the ink in the dot over this letter i! With weight, as with distance, scientists are seeking to measure smaller and smaller, as well as larger and larger, objects. In your readings you may learn how the tiniest and the most immense things ever weighed have been weighed without the use of balances!

Time

Distance, area, volume and weight are only a few of the things that can be measured. In our modern world with its speedy transportation and communication, many other things such as time, motion, position and even weather must be measured. Can you imagine what life would be like without compasses, thermometers or clocks? What would happen to ships and planes if

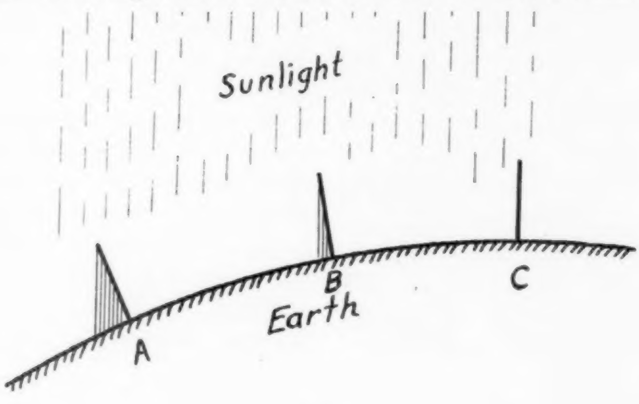
they had no compasses to guide them on their journeys? What would become of all the things made from metals or plastics whose manufacture depends upon carefully controlled temperature? What would we do without clocks? Our lives are regulated by clocks from the time we awake until we go to bed. School, play, television programs, recorded music, and even the pies your mother bakes are regulated by time. The last thing many persons do before they go to sleep is set the alarm clock to wake them in the morning. What confusion we would have without timepieces!

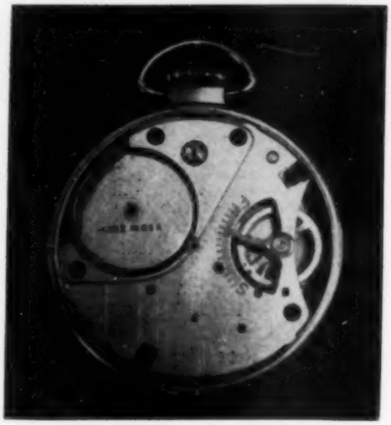
Long, long ago there were no clocks as we know them today. People had only the sun and the shadows it cast to help them tell time. Their sun dials were made to tell the time at one spot, but they could not tell the time east or west of there. If a man looked at his sundial and saw the shadow of the gnomon (no′mun) pointing at 12 o'clock, he could say, "Now it is noon." His neighbor to the east would say, "It is *past* noon," but his neighbor to the west would say, "It is *nearly* noon." Their sun dials would not agree. The diagram on this page may help you see why this is true.

To avoid the confusion that such "sun-time" causes, *time zones* have been established across the earth. The clocks in each time zone are set to read the same, but the time in adjacent zones differs by one hour.

You know that the earth makes one complete turn of 360° in 24 hours. If you divide the 360°

"A" is west of "B" and "B" is west of "C". When it is noon at "C", morning shadows are still long at "A". What will it be like at "C" when it is noon at "A"?





The escapement of this watch can be regulated by moving the pointer toward "F" (fast) or "S" (slow)

into 24 equal parts, there will be 15° in each part. Each part, shaped somewhat like an orange-slice, corresponds roughly to a time zone. Since the prime meridian (the line of 0° longitude) runs through Greenwich, England, the 15-degree zone that includes Greenwich is the zone on which all others are based.

Suppose, for example, that it is 7:00 P.M. in Greenwich. Fifteen degrees farther west is only 6:00 P.M. Thirty degrees west of Greenwich it is only 5:00 P.M. and so on. New York State lies about 75° west of Greenwich, so our clocks would read only 2:00 P.M. (five hours earlier than those in England). In California, the clocks would show only 11:00 A.M., and in Hawaii, only 8:00 A.M.

In the United States there are four standard time zones; Eastern, Central, Mountain, and Pacific. You can easily see how the time zones in our country differ if you will watch a "live" television program from the west coast late in the afternoon. You can see the sun shining in California when it is dark in New York State. Suppose it is 2:00 P.M. in a New York State school. What time would it be in a Chicago school (Central time)? in a Denver school (Mountain time)? in a Los Angeles school (Pacific time)?

If you look at a map of the time zones of the world, you will see that the time belts are not always bounded by straight lines. This is because occasionally a straight line separating two time zones might run through a city, or between two neighboring cities. You can see how confusing it would be for two parts of a city, or two neighboring cities to have different times. So the boundaries of the time zones are established where they will cause least confusion to the people concerned.

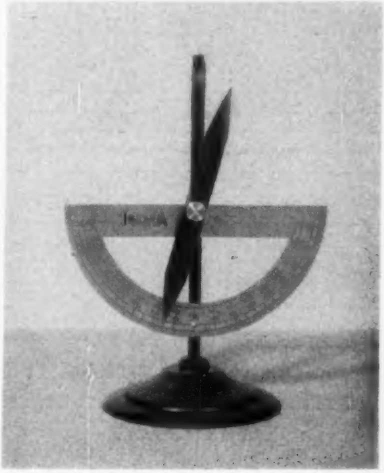
Clocks and watches are the machines we use most to measure

time. All clocks, from the earliest waterclocks and hour-glasses to the modern electric clocks, make use of some device to make their parts move at a *constant* rate. In some clocks a pendulum is used to regulate the rotating hands. Watches use a wheel that rocks back and forth instead of a swinging pendulum. The mechanism that changes a back-and-forth movement into a steady rotation is called an *escapement*. Can you see the escapement in a clock at home? It is fascinating to watch. Many modern electric clocks are made to rotate "in tune" with the alternating current in the wires that supply them. The alternations of the current are kept constant by a complicated mechanism at the power plant.

As you study time and the devices we use to measure it, look for the adjustments that speed up or slow down our clocks. One simple method is to shorten or lengthen a pendulum. Experiment with a pendulum yourself by letting a weight swing back and forth at the end of a string. Count the number of pendulum swings in a minute. Lengthen the string a few inches and count the swings again. How have they changed? Look for other ways in which clocks are regulated.

Distance, area, volume, weight and time are dimensions that you can measure with such things as rules, scales and clocks. As you learn more about science you will find other dimensions that are equally important and just as easy to measure. A few are latitude, longitude, temperature, air pressure, velocity and acceleration. You can even use a height-finder to determine latitude (sight on Polaris!). Can you find ways to measure the other dimensions? The books in your library will help you. Curiosity and imagination will help, too!

A dipping needle uses a protractor to show the vertical angle of the earth's magnetism. Can you find out about other uses of a dipping needle?



Some Helpful Books and Pamphlets

THE SIZE OF IT by Ethel S. Berkley. William R. Scott, Inc., New York. 1950. Unpaged. An appealingly simple description of the meaning of such size-words as "big," "little," "narrow," and "wide." Illustrated with black and white sketches. Primary.

THE AMAZING STORY OF MEASUREMENT. Lufkin Rule Co., Saginaw, Michigan. 1957. 23 pages. A cartoon-type booklet, in color, about the development of accurate standards of measurement. Intermediate, Upper.

HOW MUCH AND HOW MANY by Jeanne Bendick. McGraw-Hill Book Co., Inc., New York. 1947. 179 pages. A complete and well-written description of the origin and use of our common units of distance, weight and time. Also included are chapters on measurement in cooking, photography, ballistics and weather. Illustrated in black and white sketches by the author. Intermediate, Upper.

UNITS AND SYSTEMS OF WEIGHTS AND MEASURES by Lewis Judson. National Bureau of Standards Circular 570, U.S. Government Printing Office, Washington 25, D.C. 29 pages. The origin, development and present status of units of time, weight, distance, area and volume. The booklet contains detailed tables of equivalents of weights and measures. Upper.

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